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Power Quality Improvement for Mircrogrid in Islanded Mode

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Abstract

The aim of this paper is to analyze and improve the power quality of island microgrid assuming that the distributed generators could meet the load active power requirement. The main power quality problems through analysis are the harmonics caused by power-electronic devices and voltage variation caused by high reactive power requirement. Based on economy and compensation performance, a combined system constructed by SVC and SAPF is designed to improve the power quality of microgrid in this paper, in which SAPF is adopted near the microsource to mitigate harmonic currents and SVC near the load to compensate reactive power so as to relieve the voltage variation. Simulation results show the effectiveness of the combined system.

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Keywords: v/f control scheme; microgrid; power quality; APF; SVC

1. Introduction

Distributed generation systems based on renewable energy sources, (such as solar energy, wind turbines, hydroelectric power, bio-fuels and the utilization of waste products as fuels etc[1][2].) is expected to be widely implemented in the coming years. However, application of individual distributed generators can cause as many problems as it may solve. A better way to realize the emerging potential of distributed generation is to take a system approach which views generation and associated loads as a subsystem or a "microgrid"[1].

Compared with traditional configuration networks, Micrgird has its own power quality problems due to the network structure, special operation characteristics, kinds of storage and detection devices included[3]. Generally, the power quality problems can be classified as three kinds: one is caused by

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microsources (such as the unstable output of renewable energy sources such as photovoltaic and wind farms); other is harmonics which caused by power electronics adopted in microgrid, and the last is the voltage sags caused by increasing load reactive power demands.

Assuming the distributed generators (DGs) could meet the load active power demands, this paper did the researches on power quality analysis for microgrid in islanded mode and proposed that the main power quality problems were harmonics caused by power electronics and voltage sags caused by increasing load reactive power demands.

Actually, both APF and SVC can achieve harmonic currents elimination and reactive power compensation. However, the two kinds of equipments have their own merits and demerits: with faster response speed than SVC, APF can be used to meet real-time requirement, but APF with a big reactive power capacity is much more expensive.

Therefore, based on economy and compensation performance, a combined system constructed by SVC and SAPF is designed in this paper to improve the power quality of microgrid, in which the SAPF is closed to the microsource and the SVC is set near the load, so as the coupling between APF and SVC can be avoided when SAPF and SVC work simultaneously. And the results obtained from the simulation verified the APF+SVC performance.

2. Microgrid control strategy in islanded mode and power quality problems

Currently, there are two kinds of control strategy for microgrid in researching, central control strategy and peer to peer control[1][4]. In peer to peer control, every microsource needs to be properly controlled to sustain the voltage and frequency stable in a certain allowed range. This problem needs more attention in islanded mode because the microgrid cannot get voltage and frequency support from utility any more. This paper adopted the common used voltage-frequency control strategy[5][6]. The control scheme is shown as fig.1.

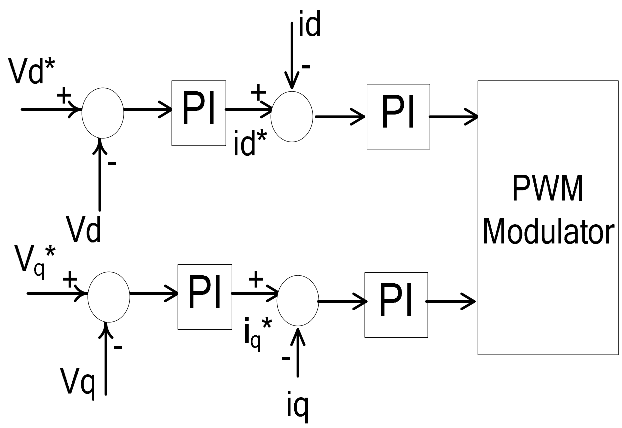

Fig. 1. V/f control scheme in island microgrid

As this paper focused on power quality improvement for microgrid, the power quality problems caused by microsources were not considered. And because this paper assumed the microsources could meet the loads active power demands, the frequency of the microgrid could keep stable. (The microsources and storage devices together could supply enough active power for load, and if the loads active power demands are beyond microgrid ability, the microgrid will adopt cut loads to restore the frequency). The simulation results of the microgrid implementing vf control strategy in matlab/simulink show that the load current contains harmonics and the voltage fluctuates with the increase of load reactive power demands. Therefore, we can get the conclusion that the main power quality problems of microgrid in islanded mode were harmonics caused by power electronics and voltage fluctuates caused by increasing load reactive power demands.

3. Combined System for power Quality Improvement

Based on the power quality problems and the reasons, the combined system is adopted considering its economy and compensation performance. The main problems for combined system are how to design the combined system structure to avoid the coupling between SVC and SAPF and to make the combined system stable. That means the control of SAPF and the control of SVC should not form a closed loop. Base on the theoretical analysis and simulation tests results, the whole structure of the combined system in this paper is as: the SAPF is closed to the microsource and the SVC is set near the load, so the coupling between APF and SVC can be avoided when SAPF and SVC work simultaneously.

3.1. APF

Based on the way of the access to the network, APF can be devided into three types: serial, shunt, serial-shunt. With the advantages of flexible switching, simple protection equipments, Shunt APF is the most common technology. The SAPF principle of operation is as follows: the current is detected first, and then the compensation current instruction signal is obtained by instruction current calculation circuit, the actual compensation current is finally gained after signal amplification by the compensation current generator. The compensation current offsets the harmonics and reactive current to get the desired current eventually. Therefore, two critical problems need to be solved: how to detect the compensation current and how to control the actual compensation current follow the change of the demanded current.

The current detection for SAPF is based on three-phase circuit instantaneous reactive power theory[8][9]. Here we adopt Ip-Iq method which is presented in Fig. 2. And hysteresis-current control method-- the most widely used nonlinear closed-loop current control method—is adopted in this paper.

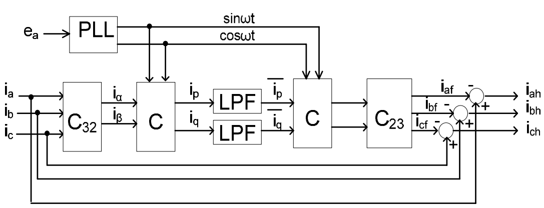

Fig.2. Ip-Iq compensation current detection method

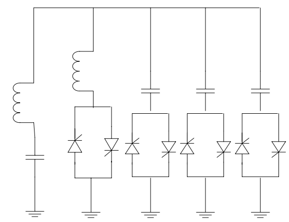

Fig.3. SVC configuration

3.2. SVC

With the advantages of high performance, mature technology, and high reliability, the Static Var Compensator (SVC) is a shunt device which is able to continuously and dynamically adjust reactive power compensation. The basic components of SVC are Thyristor Controlled Reactor(TCR) and Thyristor

Switched Capacitor(TSC). The scheme of SVC is shown as fig.3[11], where the filter is employed to eliminate the harmonics generated by SVC.

Both SAPF and SVC in proposed combined system have mature control strategy respectively. The main creative point of this paper is the combined system, and therefore the paper adopted the common control strategies of SAPF and SVC to test the feasibility of the combined system. The future work is to improve the control strategies to get better compensation performance.

4. Simulation Results

The proposed system is verified in Matlab/Simulink simulations. The frequency of microgrid is 50Hz. The parameters used for simulations are given in Table 1.

Table 1. System parameter

R_{line}/X_{line}	5Ω/1e-3 H
P_{LOAD}	adjustable
Q_{LOAD}	adjustable
L(LC Filter)	0.06H
C(LC Filter)	2e-5 F
Vf outer loop PI parameters	Kp=1.5 , Ki=40
Vf inner loop PI parameters	Kp= 1, Ki=20
PWM carrier frequency	3000Hz
Simulation sampling time	5e-5 s

Because we assume that the microgrid could afford loads active power demands, the frequency can be stable at 50Hz, and therefore, the frequency simulation result was not shown is this paper.

First, when the load reactive power demand is 100Var, the simulation results are that the voltage is in a good state and the current contains a little distortion, and the reason for that is the application of electronic devices in the microgrid. To save space, the figures are omitted. Then the the load reactive power demand increases to 5000Var and the active power is 10000W, the voltage(a phase), current(a phase)and current FFT analysis are shown in fig4. From that we can see the current of the microgrid contains harmonic contents and the THD of current reaches to 12.28%, and the voltage fluctuates because of the higher reactive power demand.

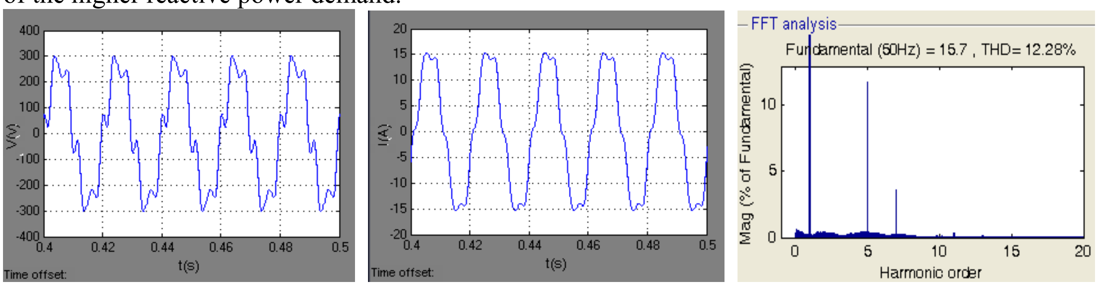

Fig. 4. Microgrid simulation results

After applying the combined system to DG system in the microgrid, the simulation results are shown in Fig.5. It can be seen that the power quality has been greatly enhanced, where the voltage becomes steady and THD of current drops to 1.44%.

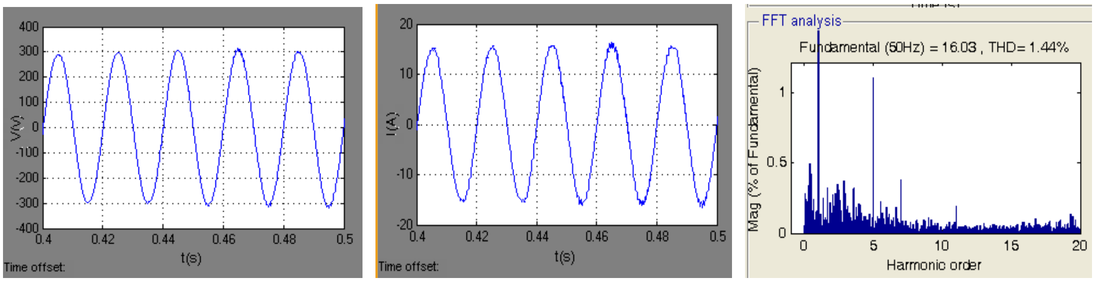

Fig. 5. Microgrid simulation results with combined system

To testify the effectiveness of the proposed system, power quality improvement strategy comparisons are shown in Table 2 (because the frequency of microgrid in different situations can be stabilized at 50 Hz and meet power quality demand, we omit it here to save space). The strategies are designed as using no improvement equipments (DG alone), APF only, SVC only, and the combined system to the microgrid. From the table we can see that with the increase of the reactive power demand of load, the power quality of voltage goes down if there is not enough reactive power compensation. APF has the best performance among the strategies in harmonic elimination. SVC only can compensate reactive power to improve the voltage quality. However, the APF only cannot compensate reactive power effectively for the microgrid because of its capacity limit, and SVC only has less effectiveness in harmonic elimination. And the combined system has the best effect according to comprehensive comparison. Based on the analysis above, we can get the conclusion that the combined system is the optimal strategy for power quality improvement for microgrid in islanded mode.

Table 2. Power quality comparison of different strategies

Load demand	Strategy	Voltage		Current	
		Amplitude(V)	THD	Amplitude(A)	THD
P_{LOAD}=5000W Q_{LOAD}=1000Var	DG+APF+SVC	311.1	0.94%	9.194	1.77%
	DG+APF	311	1.88%	9.342	1.23%
	DG+SVC	311.6	2.39%	9.208	3.56%
	DG Alone	310.8	11.43%	9.335	7.25%
P_{LOAD}=5000W Q_{LOAD}=3000Var	DG+APF+SVC	311.4	1.28%	9.222	3.18%
	DG+APF	311.5	3.2%	10.63	1.45%
	DG+SVC	311.8	1.2%	9.198	3.02%
	DG Alone	311.5	11.51%	10.63	4.88%
P_{LOAD}=10000W Q_{LOAD}=5000Var	DG+APF+SVC	313.2	1.26%	16.13	1.44%
	DG+APF	270.9	14.01%	15.36	6.18%
	DG+SVC	311	1.31%	16.02	2.27%
	DG Alone	277	24.63%	15.7	12.28%

5. Conclusion

In this paper we proposed a combined system constructed by SAPF and SVC to improve the power quality of the islanded microgrid. In order to avoid coupling, the SAPF is adopted near the microsource to mitigate harmonic currents and SVC near the load to compensate reactive power. To make the combined system more practical, it is applied to microgrid with the most common Vf control strategy. The simulation results confirm the effectiveness of the system. Compared with using APF or SVC only, the proposed approach shows a better performance in power quality improvement. The main advantages of the combined system lie on low cost, flexible control, easy realization and good performance.

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